What actually controls evolution? What is the ultimate goal?

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Abstract

The article discusses the main properties of the evolutionary process, as the transition of a "system" from a non-equilibrium state to an equilibrium one, common to various systems. The evolution of any system is determined by its "desire" to lower the energy, and the end result of evolutionary changes is the state of the system with the lowest possible energy. The discrete nature of changes in the system determines the multi-stage evolutionary process, which can be represented as a chain, each link of which corresponds to an intermediate non-equilibrium state of the system. The transition to the next link in the chain is associated with the accumulation in the system of quantitative changes that are incompatible with the "structure" of the previous link. The transition times between the links of the chain decrease sequentially, which indicates an acceleration of the evolutionary process; the times of successive transitions are related by the ratio $T_4(T_1)^{1/2} = T_3(T_3)^{1/2}$.

Introduction to the problem

So evolution. At the mention of this word, the reader almost certainly begins to think of the Charles Darwin theory of evolution, which he outlined in his work "On the Origin of Species" [1]. Only specialists working in the field of biology know that there were other theories of evolution that tried to explain the change in the forms of flora and fauna over time. Main among them were the Jean Baptiste Lamarck theory of acquired traits [2] and the theory of catastrophes by Georges Cuvier [3]. However, none of the theories of evolution, including the Darwin's theory, says anything about whether the evolutionary process is infinite in time or it is finite, i.e. evolution has its end. In the latter case, an important question arises – What is the ultimate goal of evolution, i.e. what should the evolutionary process eventually lead to?

We can find the answer to this question if we expand the horizon a little, leaving the plane of the evolution of biological forms. Although evolution is usually understood as development in time, which leads to the complexity of the organization, the concept of evolution is much broader and can be applied to a variety of processes in the surrounding world. Indeed, any spontaneous change over time in the state of the "system" (which can be understood as a certain set of interacting physical objects) can be defined as its evolution. It is this definition of evolution that the author uses below in the article. For example, a physico-chemical system can be in one of two states, non-equilibrium and equilibrium, and its transition from non-equilibrium state to an equilibrium one can be defined as the evolution of the system. It is known from the course of thermodynamics that the possibility of a chemical process is determined by a decrease in the Gibbs energy $\Delta G = \Delta H - T\Delta S$ [4]. Thus, the chemical reaction is controlled by the factor of energy stabilization of the system.

It can be assumed that changes in time in any system, if they occur spontaneously, are determined by the "desire" of the system to lower its energy. In other words, the direction of the evolution of the system is such that in the course of evolution, the energy of the system must decrease until it reaches a state with the lowest possible energy. This state can be considered as the end result of the evolution of the system. The reader can easily recall many examples of such an evolution from different areas of natural science. For example, chains of α-radioactive decay, when an unstable uranium atom in the course of successive radioactive transformations with the loss of an α-particle turns into a stable lead atom. Another example - from the field of astrophysics - is the evolution of "hot" stars with their successive transformation into cold "dead" stars.

Here the question would be quite appropriate - What relation to biological objects, which are self-developing and self-organizing systems, have the examples considered above? At first glance, there can be nothing in common. However, the division of the surrounding physical world into "inorganic" and "organic" is rather artificial, because the laws governing the evolution of matter must be general. It can be expected that the features of the evolution of biosystems also reflect the movement of the system along the energy gradient, which is determined by the properties of the control field. It is difficult to imagine that the properties of the fields governing the evolution of various systems are fundamentally different. On the contrary, it can be expected that the evolution of all systems obeys the same law common to various forms of the field. In the following sections, the author considers the characteristic features of the evolution process on the example of a number of well-known systems.

Features of the evolution of systems

1. *Discreteness*. One and, perhaps, the main feature of the evolutionary process is its discreteness, when the system passes from the initial non-equilibrium state to the final equilibrium state through several intermediate non-equilibrium states. For example, the α-radioactive transformation of uranium into lead mentioned above occurs in several stages. In particular, the

α-radioactive decay chain for U^{227} has the following form: $U^{227} \Rightarrow Th^{223} \Rightarrow Ra^{219} \Rightarrow \dots \dots \Rightarrow Pb^{207}$. We see that uranium 227 after the loss of an α-particle by the nucleus of an atom turns into thorium 223, which, in turn, in α-radioactive decay produces radium 219, etc. [5].

It should be noted that in the literature, discreteness is considered to be exclusively a property of the microcosm, which is always opposed to the macrocosm. In this respect, studies in the field of atomic spectroscopy are indicative. Classical physics could not explain the discrete nature of the radiation spectrum of a hydrogen atom, which is known to be due to the existence of allowed energy levels for an electron in the atom [6]. Upon the transition of a hydrogen atom from an electronically excited state to the ground state, an electron can pass only between the orbits allowed for its motion that determines the discrete nature of the radiation spectrum. Thus, the "evolution" of the hydrogen atom from the initial non-equilibrium (electronically excited) state to the final equilibrium state, i.e. the state with the minimum total energy of the atom, is the transition of the atom through a series of discrete non-equilibrium (excited) states with a gradual decrease in the energy of the atom. The failure of classical physics to explain such a behavior of the simplest physical system, which is the hydrogen atom, led to the development of a new theory known as quantum mechanics [7].

However, in reality, discreteness is a general property of the evolution of systems belonging to both the microcosm and the macrocosm. In the latter case, in order to "see" the discreteness of the evolution process, you need to use a different time scale. An example is the evolution of a star, which consists in changing its mass, temperature, and luminosity [8]. Due to these changes proceeding billions of years, the star goes through a series of specific stages; each stage corresponds to a star of a certain type with its own unique characteristics. In other words, in the course of the evolution of a star, one can observe consistent changes of its type, which represents a certain stage in the evolutionary process. Thus, we again have a pattern of a discrete evolutionary process with a chain of changes in the state of the star upon its transition from the initial state to the final one. The number of links in this chain, where each link is a star of a certain type, depends mainly on the mass of the original star.

Another example of the discrete nature of evolutionary changes taking place in the macrocosm is the geological processes on our planet. In particular, the evolution of the earth's crust included several stages, during which a picture with the present position of the continents on the world map was formed. It should be said that geological changes turned out to be closely related with the evolution of flora and fauna on the planet. This circumstance was noted in the theory of evolution proposed by Georges Cuvier [3]. Based on the data of paleontological studies, he drew attention to the spasmodic nature of the change in flora and fauna, when each period of time on the planet has its own unique biological species.

Apparently, the appearance of man on the planet was the last link in the chain of evolution of biological forms. From this moment, the evolution of human society begins or, more exactly, the evolution of socio-economic relations, during which humanity has passed through several well-known socio-economic formations [9]. Each of these formations represents a certain stage in the development of social-industrial relations and productive forces. Thus, the evolution of human society can be defined as a sequential transition in time from one socio-economic formation to another; at the same time, each subsequent formation corresponds to a higher level of productive forces and fewer contradictions in production relations.

In fact, here we have the same discreteness of the evolutionary process when the system moves from the initial non-equilibrium state to the final state of equilibrium between productive forces and production relations. At present, our knowledge of fields and their properties is very scarce; however, it can be assumed that the evolution of humanity as a society of individuals is governed by the same law of the movement of the system to a minimum of energy.

2. *The transition of quantitative changes into qualitative ones.* What determines the transition of the system from one state to another state, fundamentally different in its characteristics? The answer to this question turns out to be quite simple: such a transition occurs as a result of the accumulation of quantitative changes in the system. A good illustration is the evolution of biocenosis. The changes of flora and fauna in time on an initially uninhabited land area are the simplest example. If these are temperate latitudes, then at first the area is populated with light-loving plants and tree species, and a deciduous forest is formed. After a while, shade-tolerant coniferous trees appear and the deciduous forest turns into a mixed forest. Since coniferous trees grow faster than deciduous ones, the corresponding quantitative changes in the composition can eventually lead to the death of hardwoods; as a result, the forest becomes completely coniferous. In accordance with these changes, one can see changes in the composition of the undergrowth and in the animal world.

The triangle "heredity – variability – natural selection" of the Darwin theory [1] represents the mechanism of accumulation of quantitative changes in the biosystem. Obviously, this theory well explains the "evolution" of the signs of plant and animal forms at a specific time interval, which corresponds to a certain link in the evolutionary chain. However, at some point in time, the accumulated quantitative changes turn out to be incompatible with existing types of biological objects or, what is the same thing, with the existing structure of the biosystem. As a result, a "qualitative leap" occurs with the transition of the system to the next link in the chain of the evolutionary process. This leap can be defined by the word "revolution", since fundamentally new biological forms, the structure of which is more perfect, appear on the planet. Although on the other hand, the same leap can also be called a "catastrophe", because it means the death or "evolutionary defeat" of the biological species that previously inhabited the planet. It was this term that Georges Cuvier used in his theory of evolution [3], who accurately noticed the essence of the changes taking place.

A clear example of the role of quantitative changes in the evolutionary process can be the evolution of a star. The combustion of hydrogen in a thermonuclear reaction in the bowels of a giant blue star results in its transformation into a white star, i.e. into a star of a different class with a different luminosity, surface temperature and other distinguishing characteristics. Further, helium enters into thermonuclear reactions, after the combustion of which the white star turns into a yellow one, representing the next link in the chain of star evolution, etc. It should be said that the evolutionary processes occur in accordance with the basic laws of dialectics, which were formulated by classical German philosophy back in the 18th century. There are three of these laws: "the unity and struggle of opposites", "the transition of quantitative changes into qualitative ones" and "negation of negation" [10]. Perhaps the best illustration of the work of these laws is the evolution of socio-economic formations during the development of human society.

The process of changing socio-economic formations has been well studied by historians and economists, and the causes and mechanisms of humanity's transition from one system of economic activity management to another are known. It is believed that the development of productive forces comes into conflict with the production relations that are characteristic of this socio-economic formation. The "struggle" of productive forces and production relations at a certain stage, when the "quantitative changes" of productive forces are already sufficiently large, leads to the revolution and breaking of old production relations. As a result, there is a transition of society to a new socio-economic formation with "qualitatively new" production relations that better correspond to a higher level of development of productive forces.

Thus, the new socio-economic formation "negates" the old socio-economic formation. In the course of the development of socio-economic relations, we observe several such transitions between formations, and the chain of evolution contains five links known as the primitive communal system, the slave system, feudalism, capitalism and socialism. It can be said that each subsequent socio-economic formation negates the previous one that can be defined as "negation of negation". How can we not recall here the brilliant statement of the founder of German classical philosophy, Georg Hegel: "everything that exists is worthy of destruction" [10].

3. *Acceleration of the evolution process.* Perhaps the most interesting question is what determines the moment when quantitative changes in the system lead to its transition to the next link in the chain of the evolutionary process, i.e. when a "catastrophe" occurs and the system (object) ceases to exist in its previous state (form). It is quite obvious that the peculiarity of evolutionary processes is the acceleration of evolution in time. Indeed, one can see how quickly humanity moved from feudalism to capitalism, while the primitive communal system existed for more than a million years. The same acceleration in time is observed for the evolution of biocenoses, stellar systems and fairly simple physico-chemical processes upon the transition of the system from a non-equilibrium state to an equilibrium one. In other words, when moving along the chain of evolution, the transition from one link to another is successively shortened in time, i.e. the time of the "life" of the system in each subsequent state becomes shorter and shorter.

Since acceleration is characteristic of a variety of evolutionary processes, it can be assumed that the change of the state of any system in time obeys some general law, which is determined by the properties of the field. And the observed processes themselves are various manifestations of the perturbed field, which controls the transition of the system to a state of lowest energy. The obvious question that arises within the framework of such an interpretation is the question of whether there is some kind of "equation of evolution" that is common to all evolutionary processes and establishes the relathionship between the links in the chain of evolution?

A very long time ago, when the author was a student, he used a relatively simple mathematical model to describe the chain of successive transitions of the system from the initial non-equilibrium state to the final equilibrium one during its evolution. This model establishes the relationship between the times of the system transitions between the links of the evolution chain, i.e. between the times of the system "life" in intermediate non-equilibrium states. It should be said that at present the applicability of this model for description of evolutionary processes cannot be rigorously justified. For this reason, in this article, the author decided not to discuss the mathematical model he used earlier and presented below a ratio for the evolution times without its derivation.

Suppose we are considering some kind of evolutionary process, which can be schematically represented as the following chain of successive transitions $A(T_1)$ ---> $B(T_2)$ ---> $C(T_3)$ --->

$D(T_4)$ ---> E. Here A and E are the initial and final states of the evolving system, respectively; B, C and D are chain links that correspond to intermediate non-equilibrium states of the system formed during evolution. The symbols T_1, T_2, T_3 and T_4 denote the times of successive transitions between the chain links, i.e. the lifetime of the system in the corresponding non-equilibrium states. It follows from the mathematical model that the course of evolutionary changes will be determined by the following relation linking the lifetimes of the system in non-equilibrium states $T_4(T_1)^{1/2} = T_3(T_3)^{1/2}$. This relationship between the times of a system transition from the previous link of the evolutionary chain to the next link seems to be fulfilled for any system with a multi-stage evolution into an equilibrium state.

It should be said that in most cases there is no reliable data on evolutionary chains, in particular on the duration of separate stages of the system evolution. Very often it turns out to be problematic to correctly identify the chain itself, determining the initial state of the system and the intermediate links. Perhaps, chains of radioactive transformations represent one of the few examples of a system with a multi-stage evolution for which there is reliable data on the successive stages of evolution of the atomic nucleus. In particular, for the chains of α-radioactive transformations of uranium 227-232, reference manuals give the half-lives of elements in the corresponding chain, i.e. the transition times between the links of the evolutionary chain [5].

The most striking example of the acceleration of the evolutionary process in time is the change of socio-economic formations in the history of mankind [9]. Indeed, if we believe the research of historians, the time of existence of the primitive communal system was more than a million years, slavery is about 3.5-4 thousand years, whereas the stages of feudalism and capitalist formation lasted only 1000 years and 200-300 years, respectively. It is not difficult for the reader to verify the validity of the above ratio of times on the example of the "lifetime" of humanity in each of the socio-economic formations passed. So, it follows from the ratio that $T_4 = T_3(T_3)^{1/2}/(T_1)^{1/2}$ and for the estimated duration of the socialist formation, the calculation gives about 50-80 years. This result is in good agreement with the time of existence of the socialist camp countries.

Conclusions

Thus, consideration of the evolution of very different systems allows us to identify several common properties of the evolutionary process:

1. *Discreteness.* In general case, the evolution of the system is multi-stage when the transition of the system from the initial non-equilibrium state to the final equilibrium one passes through

several intermediate non-equilibrium states (stages). In other words, changes in the system in time can be represented as an evolutionary chain containing several links.

2. *The transition of quantitative changes into qualitative ones.* The movement of the system along the evolutionary chain is determined by the accumulation of quantitative changes. At a certain point in time, quantitative changes in the system become incompatible with its "structural organization", which leads to a qualitative change in the structure of the system. What is happening can be called a revolution, because a fundamentally new structure appears, which means the transition of the system to the next link in the chain of the evolutionary process.

3. *Acceleration.* With the course of the evolutionary process, its acceleration in time is observed, when the time of transition to each next link in the chain of evolution of the system is consistently reduced. The times of successive transitions of the system, i.e. transitions between adjacent links of the chain, are related by the ratio $T_4(T_1)^{1/2} = T_3(T_3)^{1/2}$. The ultimate goal of the evolutionary process is for the system to achieve a state with its minimum energy, i.e. a global minimum. If the intermediate non-equilibrium states of the system are metastable, then they must correspond to local minima on the energy surface. Then a sequential decrease in the transition time between the links of the evolutionary chain means that the depth of the local minimum and the lifetime of the system in a metastable state decrease with the course of evolution.

Apparently, the evolution in its various manifestations describes the transition of the field from a perturbed state to a state of rest. Of particular interest is the question of evolution associated with the appearance of humans and their activities on the planet. The appearance of *homo sapiens* was the last link in the evolution of biological forms. This is where the "biological" evolution on the planet ended, but the socio-economic evolution of human society began. It can be assumed that by now the socio-economic evolution of mankind has also ended, because for a long time there have been no significant historical changes (revolutions).

At the same time, something happened that received the name of the scientific and technical revolution in the literature. In recent decades, there has been a rapid growth of knowledge in technical fields and an increase in the volume of scientific information, which has become increasingly difficult for humans to process. There was a situation when the growth of the flow of information came into conflict with the carrier of this information, which is the human brain. This contradiction, which deepened very quickly, at some point in time had to lead to a "revolution", namely, to the emergence of a new, more advanced information carrier capable of processing it quickly and solving complex problems using it. The first computing systems and electronic databases appeared.

The advent of computers can be considered as the first link in a new evolutionary chain. Currently, there is a rapid evolution of computer technology. Tracing the path from the beginning, we see how the very slow evolution of biological forms is replaced by a much faster socio-economic evolution of humanity, and then the ultra-fast evolution of cyber devices. Perhaps, one of the last links in this new evolutionary branch was the emergence of artificial intelligence. Unfortunately, people cannot influence the historical course of events or, at least, their final result, since they themselves are elements of a system whose evolution obeys objective laws. The scenario of evolutionary processes can be changed only by external influence on the system, i.e. by the action of something that does not belong to the system itself.

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